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Review of compliance with EU-2010 targets on renewable energy in Galicia (Spain)

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Abstract

The use of renewable energy offers a range of exceptional benefits, including: a decrease in external energy dependence; a boost to local and regional component manufacturing industries; promotion of regional engineering and consultancy services specialising in the use of renewable energy; increased R&D, decrease in impact of electricity production and transformation; increase in the level of services for the rural population; creation of employment, etc.

To achieve these benefits, a series of actions are required, among which the following are particularly important: creation of a suitable climate for performing R&D; training of technicians in design, production and maintenance of equipment; motivation for establishing a new market; proper financing; fostering of appropriate technologies; practical demonstration of results, etc.

This article reviews the progress made in the Autonomous Community of Galicia in terms of the introduction of renewable energy technologies (RETs) and examines the possibility of meeting a target of 90% coverage (practical electrical self-sufficiency) by 2010, of which 51% would come from wind power, with a saving of 4000 ktoe of primary energy, and prevented emissions of 12×10^6 t of CO_2 per year.

Keywords: Renewable energy; Energy consumption; European Union; EU targets-2010; Galicia

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1. Introduction

The problem of energy is one that has always been closely tied to the development of human civilization. Energy consumption has grown from a minimum value associated with food needs to values 50 times higher in developed societies. Until recently, a direct relationship was drawn between development—or welfare—and increased energy consumption. However, following successive energy crises, and the emergence of environmental problems on a global scale linked to the existing energy system model (strong dependence on hydrocarbons), this direct equation between development and energy consumption, is now being revised and criticised.

Most of the forecasts on trends in energy needs [1–5], indicate that a further challenge will be the likely increase in demand in certain heavily populated countries, such as China, which are advancing from underdeveloped economies to industrial-type ones, and the inevitable impact this will have on the current energy model. Against this backdrop of dependency, on the one hand, and criticism of the existing model on the other, the European Union is playing an active role in the field.

1.1. European Scenario

The development of renewable energy has long been one of the central objectives of community energy policy: in 1986 the Council of Europe mentioned initiatives to promote renewable energy sources as being one of its energy targets [6]. Since then, significant technological developments have been made, thanks to a variety of programmes, including JOULE-THERMIE, INCO and FAIR [7]. In 1995 European Union member states consumed 1367 Mtoe (1 Mtoe $=41.868\times10^{15}$ J) of energy. Renewable energy sources contributed just 5.44% of this figure and were clearly being underused. With the ALTENER programme, the European Commission, in its White Paper 'An Energy Policy for the European Union' [8], set out its ideas on community targets, and the instruments of energy policy needed to achieve them. This document established the three key objectives of the energy policy: improved competitiveness, security of supply and environmental protection.

Greater use of renewable energy sources allows a reduction in energy imports and consequently in dependency on fossil fuels, tempering the effect of variations in oil and gas prices. Even without energy crises, bodies such as the International Energy Agency forecast continuing increases in the price of hydrocarbons—though not of coal—which need to be taken into account in planning the future framework of the electricity industry [9]. At the same time, economic growth and rising energy needs increase the risk of harm to the environment, with renewable energy sources emerging as one of the most effective solutions [10]. To achieve these objectives, the White Paper [8] says that one important factor is the encouragement of renewable energy sources (RES). The European Commission's stated goal is for such sources to meet 12% of demand by 2010. Similarly, a strategy is proposed for renewable energy sources, which is specifically set out in the 'Indicative Work Programme' attached to the White Paper on energy policy. The Commission sponsored the TERES programme in order to illustrate the potential effects that specific political initiatives can have on the field of renewable energy. The TERES II study is based on one of the hypotheses previously set out in the European Energy Commission's report to 2020.

This study predicts that a net figure of 500,000 jobs will be created throughout the EU in pursuing the target of a 12% share by renewable energy sources in energy consumption. In Spain it is estimated that about 60,000 jobs would be created.

The Kyoto Protocol to the United Nations Framework Convention on Climate Change, approved in December 1997, marks an important turning point in efforts to promote the use of renewable energy [11]. In May 2000 the European Commission presented a proposal for a directive on the promotion of electricity from renewable energy sources in the internal electricity market, setting out targets for member states on generation of electricity from renewable energy sources as a proportion of gross electricity consumption by 2010. In order to promote the use of renewable energy, the Commission adopted the 'Green Paper' [12]. Appendix II gives a summary of a series of guideline contributions planned for each renewable energy source and each market sector, as a projected means of achieving the required overall growth in RES. According to these hypotheses the largest contribution to the growth in RES (90 Mtoe) could come from biomass, where there could be a threefold increase. The second largest increase, with a contribution of 40 GW will probably be in the area of wind energy. Significant increases are also predicted in solar

Table 1
Targets by country for 2010. EU directive on promotion of electricity from renewable energy sources

	Percentage (%)	TWh	Percentage without large hydro
Germany	12.5	76.4	10.3
Austria	78.1	55.3	21.1
Belgium	6.0	6.3	5.8
Denmark	29.0	12.9	29.0
Spain	29.4	76.6	17.5
Finland	35.0	33.7	21.7
France	21.0	112.9	8.9
Greece	20.1	14.5	14.5
Ireland	13.2	4.5	11.7
Italy	25.0	89.6	14.9
Luxembourg	5.7	0.5	5.7
Netherlands	12.0	159	12.0
Portugal	45.6	28.3	21.5
United Kingdom	10.0	50.0	9.3
Sweden	60.0	97.5	15.7
EU	22.1	674.9	12.5

thermal collectors (with 100 million square metres to be installed before 2010). Lesser contributions are forecast for photovoltaic energy (3 GWp), geothermal energy (1 GWe and 2.5 GWth) and heat pumps (2.5 GWth). Hydro power will probably continue to be the second largest source of renewable energy, but the increase in this area will be relatively small (13 GW) and the overall contribution will remain at current levels. Finally, passive solar power systems might make an important contribution to reducing energy demand for the heating and cooling of buildings and an energy contribution of 10%—equivalent to a fuel saving of 35 Mtoe—is considered viable in this area. If the industrial growth used in this hypothesis is achieved, it will be possible to double the overall share of renewable energy sources.

Table 1 [13] shows the targets for production from renewable energy for 2010 by country. There is currently no harmonised European system for supporting the prices of electricity generated from renewable energy, although it is forecast that some unified system will be adopted in the future. However, member states have adopted various support mechanisms, which are helping to achieve a medium-term reduction in the cost of generation with renewable energy and an increase in the introduction of this type of energy on the internal market.

Moreover, in the area of the common agricultural policy and the rural development policy, Agenda 2000 [14,15] invites member states to encourage renewable energy sources. Biomass, in particular, must be developed by all available agricultural, fiscal and industrial means. The key recommendation of the European Conference on Renewable Energy was that the European Union should set a new medium-term target: renewable sources should satisfy at least 20% of energy consumption by 2020.

Table 2
Targets for 2010 of the plan for the promotion of renewable energy in Spain

	1990	1998	2010
Small hydro (MW)	611.8	1509.7	2230
Biomass (ktoe)	3753	3886	10,971
Wind (MW)	27.2	834	8974
Solar photovoltaic (MWp)	3.2	7.9	142.9

1.2. Spanish Scenario

In Spain, RES have been successively promoted by the 1986 Renewable Energy Plan (REP) [16,17] and the National Energy Plan (NEP) for 1991–2000 and 2000–2003. The 1997 Electricity Industry Act (54/1997) [18] prioritised deregulation of electricity market, establishing a special framework or regime for renewable energy which would allow guaranteed access to the grid, while at the same time special conditions were allowed for renewable energy sources. The main purpose of Royal Decree 2818/1998 [19–25] was to design an administrative procedure for availing of the special system. The decree also established the tariffs for each type of energy facility depending on its capacity and renewable source. RES are promoted through a set of measures with special powers granted to the regional autonomous communities. At national level these policies are framed within the Programme for the Encouragement of Renewable Energy in Spain 2000–2001[26–28]. This plan was drawn up as a response to the commitment made under Act 54/1997 [18] and its main purpose is to cover 12% of primary energy consumption with RES by 2010. Figures on energy capacity and production are shown in Table 2. Among the most important are the figure of 8974 MW in wind power which it is planned to install by 2010, and the 60% figure for biomass. Royal Decree 436/2004 [29], enacted on 12 March 2004, establishes the new methodology for payment under the special system.

According to the IDAE (the Spanish Institute for Energy Diversification and Saving), [30] in terms of primary energy, renewable sources accounted for 7173 ktoe of contribution to the national energy balance at the end of 1998. Of this production from renewable energy sources, biomass—which represents 50.8% —and hydro power (43.4%) were the leading technologies in quantitative terms. By usage, 51.2% went to producing electricity and the remaining 48.8% to heat production.

In order to understand the way Spanish legislation operates, it is important to note that the Spanish Constitution divides the power to establish energy policy between the regional and national governments. The autonomous governments are responsible for most aspects of regulation and energy sector development in their region. The central government is responsible for harmonizing energy policy at national level, promoting regional economic development, international and inter-provincial trade.

1.3. Scenario in the autonomous community of Galicia

For Galicia, the energy industry (Fig. 1) has a great strategic value, contributing approximately 8% to the region's GDP. It is also one of the main sources of employment,

Fig. 1. Geographic location of the Autonomous Community of Galicia.

providing 10,000 direct jobs and more than 22,000 indirect ones. Galicia has a land area of approximately 29,422 km^2 (5.8% of the total surface of Spain) and contains 6.9% of the total national population [31].

Primary energy sources (local or imported) are considered to be any resources that come directly from nature and which have to be transformed in order to be used and consumed. In 2002 [32,33], Galicia handled nearly 13,000 ktoe of primary energy: 3140 ktoe local and 9698 ktoe imported (principally oil and coal). An analysis of these figures shows that Galicia is a region with a large energy-transforming capacity (10% of the national total). Of this primary energy, 77% is imported (basically coal and oil) and 23% is local (coal, water, biomass, wind and waste). Through a number of different processes, this primary energy was converted into 7532 ktoe of energy available for final consumption (heat, electricity or transport uses), of which 4921 ktoe (66%) was used to cover local consumption and the remaining 2506 ktoe (34%) was exported to other regions (basically in the form of electricity and oil products). The trend in the flow of primary energy can be seen from the energy balance for Galicia shown in Fig. 2. We can see that the gradual increase in the use of primary energy was met with an increase in imports of energy resources, while local sources, though increasing, are not

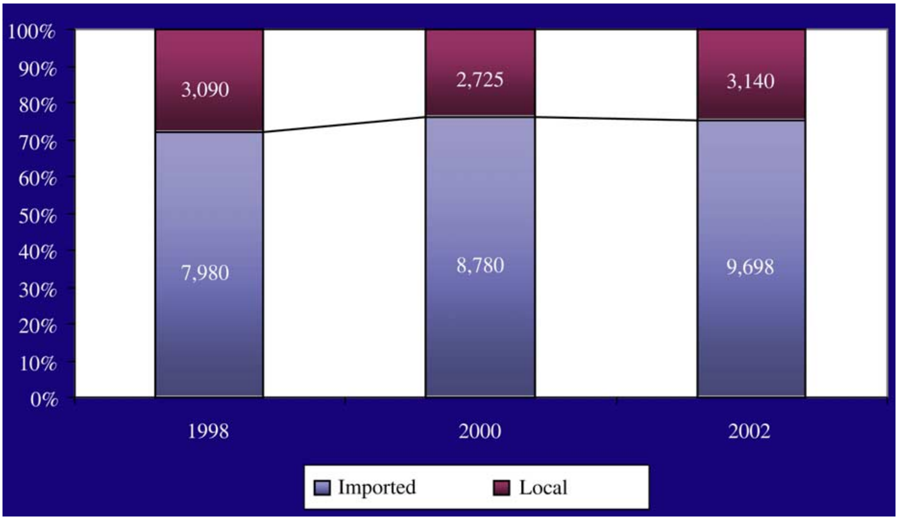
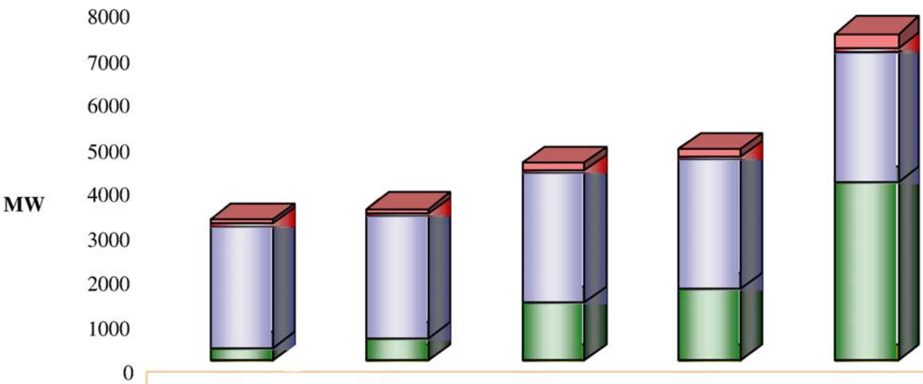


Fig. 2. Trends in flows of primary energy in Galicia (ktoe).



	1998	2000	2002	2003	2010
small hydro	115	115	173	203	315
Biomass	40	40	43	45	93
Hydro	2,759	2,759	2,945	2,945	2,945
Wind	257	487	1.297	1579	4000
Solar	0.10	0.1	0.152	0.365	5

Fig. 3. Distribution of installed capacity in Galicia by type of renewable energy. Source: Galician Ministry of Industry.

keeping pace. This is due to the fact that the growth rate of the Galician economy (like the Spanish economy as a whole) has been higher than the European average in recent years (2.8% of GDP). In terms of increase in power generation, local energy easily meets the aforementioned premise (Fig. 3). For example in 1998, hydro power had the highest percentage (87%), followed by wind (8.0%), and small-hydro (4%). Solar and biomass energy accounted for a smaller, almost insignificant, percentage.

In percentage terms, Galicia's capacity for self-sufficiency in final energy (electricity and heat) is estimated at around 53%, if we exclude the demand for petroleum products demanded for transport, and 33% if we include it. Galicia is an important energy producer in Spain: 12% of all electricity available in Spain comes from the region (32% from hydroelectric power and 15% from conventional thermoelectric power).

Galicia has an important potential for harnessing renewable energy in the area of wind power, small hydro and biomass. The Plan for Galicia sets specific targets of a 15% contribution by RES to final energy consumption, specifically 1325 GWh per year from wind power; 1082 GWh per year from small hydro and 963 GWh per year from biomass [34–36].

2. Renewable energy technologies (RET)

RETs convert renewable sources of energy to useful energy vectors, such as heat, electricity, mechanical power or fuels. The applications of the different RETs can be divided into three categories [37] (a) green power technologies; (b) green heat technologies, (c) green fuel technologies.

2.1. Green power technologies

Green power technologies can be defined as the electricity generated from RETs from renewable sources like wind, solar, small hydropower, geothermal and biomass sources.

2.1.1. Solar photovoltaic

Galicia, like most of the rest of Spain, has very favourable climate characteristics for solar power [38]. Levels of solar radiation are not very high in the region: Average daily solar radiation is 1.2–1.8 kWh/m^2 in winter, and between 3 and 4.5 kWh/m^2 in summer, compared to the Spanish average of over 5 and 7 kWh/m^2 in the south of Spain. The annual average sunshine is between 1600 and 2200 h, compared to overall Spanish figures of between 2200 and 2800 h. Although it is not the highest, it is certainly greater than the solar potential of Germany, Sweden, etc.

Despite the fact that harnessing of solar power in the region is currently insignificant, continuous progress is being made, both in terms of low temperature collectors for supplying hot water, and photovoltaic panels. There are numerous photovoltaic solar panel installations in rural areas without conventional electrification.

In 1998 Galicia had an installed capacity of 53 kWp, compared to 3953 kWp for all of Spain. The Instituto Energético de Galicia [39] has started up a programme to promote the development of solar power in Galicia. Its main objectives are: to multiply

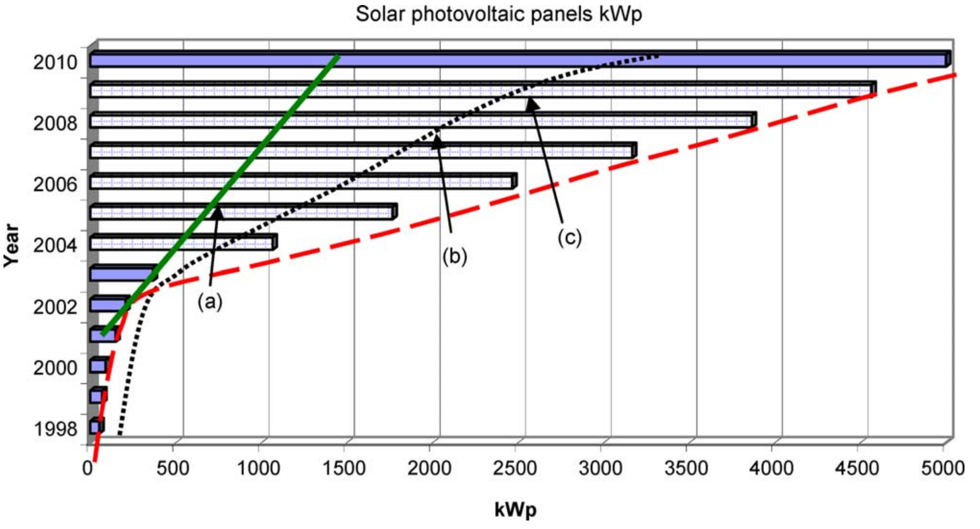


Fig. 4. Estimations for meeting the targets of the Galician solar photovoltaic plan. Source: Galician government.

by a factor of between 13.5 and 25 the installed capacity of photovoltaic solar energy (between 2000 and 3500 kW), thus achieving annual energy savings of 0.5–0.8 ktoe in photovoltaic. In 2003, for example 365 kWp was generated, a long way from the 5000 kWp targeted for 2010, as we can see in Fig. 4. According to Forecast (a), with linear growth, only 1/3 of the final target will be achieved, whereas in the case of exponential growth (Forecast b), the figure would be 60%. The target is therefore too ambitious, although a very significant increase is expected between 2004 and 2007 due to the approval of a new payment for renewables under Royal Decree 436/2004 [29] of 12 March 2004 and an increase in the capacity power of installations eligible for grants from 5 to 100 kWp. Nonetheless, solar energy's contribution to the energy balance would still only be about 2 ktoe, a relatively insignificant figure in terms of energy planning.

2.1.2. Biomass energy

Biomass is versatile since it can be used to produce electricity and heat or as transport fuel as required and, unlike electricity, it can be stored simply and normally economically [40]. Production units can vary in size from very small ones to ones of thousands of megawatts.

For the EU as a whole a realistic target is considered to be the tripling of the present figure of 44.8 million tonnes of oil equivalent (or Mtoe) by 2010, provided effective measures are taken. This would mean an additional biomass consumption of 90 Mtoe, equivalent to 8.5% of the total energy consumption forecast for that year. In some EU member states—Austria, Finland and Sweden—this renewable source of energy already represents 12, 23 and 18%, respectively, of principal energy supply.

To continue developing the biomass markets, the following measures are now being promoted:

- (Combined Heat and Power (Cogeneration).
- New urban heating and cooling networks which provide an outlet for CHP with biomass.
- Greater access to fuels from processed waste such as woodchips and fuel briquettes, and more intensive use of suitable waste from forestry and the wood and paper industries.
- Using the new reinforced integrated gasification combined-cycle (IGCC) systems, with a capacity of between 25 and 50 MWe, driven by a mixture of fuels derived from biomass and waste.
- Non-pollutant energy production from municipal waste by heat treatment, recovery of landfill gases and anaerobic digestion.
- Promotion of co-combustion [41].

Galicia has the highest potential of forestry waste of any region in Spain, with 995,000 t available per year in waste forest biomass in sustainable conditions. It has the second-highest consumption of biomass, according to data from the IDAE [30]. Estimates based on figures from the Third National Forestry Inventory [3] suggest that the amount of biomass in Galicia comes to 609,000 t per year.

Climate conditions, population distribution and the long tradition and importance of timber plantations in the region give a considerable potential for this type of energy. This figure represents 450 ktoe of energy per year (17% of the national total).

Here, we distinguish between natural waste, the results of consumption processes (MSW) and waste resulting from transformation processes.

2.1.2.1. Forest waste. These projects for harnessing forestry biomass for energy purposes must be framed within integrated management of mountain areas. There are certain benefits, such as the contribution to improving management of mountain areas (hill clearing, fire prevention), harnessing of natural waste for energy production and job creation. But there are also barriers, including the alternative uses of the by-product of the wood industry, the fact that the availability of the resource is limited depending on the site and the need to improve transport logistics.

The total balance of the waste produced and used in 2000 in Galicia is expressed in toe (tonnes of oil equivalent) per year and divided into forestry waste produced on mountains with a capacity of 170,496 toe per year, and forestry waste produced in industry, which comes to 224,064 toe per year.

In order to assess the energy potential of forest waste, two groups were defined: waste from timber treatments (primary processing) and those resulting from the wood processing industry (furniture and carpentry). The waste (40%) produced in the wood chain is generated on mountainsides, 30% in preparation of boards and laminates, 16% in sawing, 10% in pulping and 4% in carpentry and furniture.

Waste from primary processing represents a high risk factor if it is not removed. However, this process takes place as part of a commercial activity, which can make it

easier to collect for use in the energy field. For this, it would be necessary to establish a collection and treatment system in the field, consisting basically of the following operations: cutting, extraction, chipping and primary transport. This way, the product obtained could be taken to a treatment plant, where the main operations would be: storage of raw materials, crushing, milling, drying and storage of finished products.

Galicia currently has four thermal power plants, with a combined total of about 40 MW of installed capacity. Consumption of biomass is 232 ktoe, contributing 153 ktoe of heat energy and 5 ktoe of electricity. As already mentioned, the potential of forest biomass is around 995,000 t per year. This would allow 100 MW to be installed from the fuel generated in clearing hills, which would generate 68 ktoe. By 2010 it is planned to install 50 MW of electricity, generating 34 ktoe, and viability studies have already been carried out for installation of a 10 MW plant. The Plan for the Promotion of Renewable Energy in Spain proposes an important development in the area, based on the capture of 2.65 Mtoe of waste.

Finally, in thermo-electric applications it is proposed to install 1708 MW of power, generating 11,913 GWh per year of electricity, by 2010; the investment required by 2006, would come to €1.55bn. Summing up, the area of biomass is the most substantial feature of the plan, contributing 63% to energy targets. The promotion plan's forecasts for development of biomass as an energy sources are not being met, because of the low profitability of the projects. One of the critical points involves the costs of transport and storage.

2.1.2.2. Biogas and municipal solid waste (MSW). Biogas is generated by means of anaerobic decomposition of the organic matter in MSW. The main stages in the formation of biogas are: hydrolysis, autogenesis and finally methanogenesis. The biogas thus generated can be used as fuel to generate power using internal combustion engines, with the possibility of harnessing the heat energy from the combustion gases and the cooling engines, to cover the heat requirements of the plant itself (cogeneration).

Currently in operation is the MSW powered plant in Nostián (Coruña.) which is a 6.27 MW biogas plant with an energy production of 4.6 ktoe. The plant can treat about 135,000 t per year of Municipal Solid Waste, making it largest-capacity facility of its kind built to date anywhere in Europe. Other facilities include the 2.27 MW Biocerceda plant (Cerceda) and a 2.5 MW CHP plant at the landfill in Bens (Coruña) which uses biogas. [42]

Waste water treatment plants also have great potential in terms of energy resources. There is a 0.24 MW project for the Orense station. If this same technology were applied to the 20 largest cities in Galicia, a combined energy production of 13 ktoe could be achieved.

In the National Plan, the potential of resources is valued at 546.4 ktoe, of which the Plan proposes that 78 MW be exploited, with a production of 494 GWh per year, equivalent to 150,000 toe of primary energy. In the area of Municipal Solid Waste, the plan proposes installation of 168 MW to 2010, generating 1037 GWh per year, equivalent in primary energy terms to 435.6 ktoe [30].

2.1.3. Wind energy

The great technological development experienced in the wind industry and the existence in the Autonomous Community of Galicia of large areas with important resources has led to the introduction of numerous wind farms, requiring the local government to intervene to organise these resources. Decree 205/95 [43] and 302/01 [44] were issued to meet this need, for developing a programme of investments and industrial actions. Developers were also asked to give an assurance that investments would be made which would affect the regional economy (the goal is for 70% of the parts to be manufactured in Galicia).

The development of wind technology in recent years has been spectacular, both in terms of the cost of the installed kW and the availability of operation. At the beginning of the 1990s, the average power of commercially installed wind turbines came to 200 kW; by the end of the decade it had risen to 700 kW. Wind turbines are now commercially available with a capacity of 1500 kW, and the first prototypes have been built of 3.5 MW and over. Modern wind generator towers range in height from 40 to 50 m, the radius of the sails is 21 m, and the swept surface is 1375 m^2. Annual operation time at full load for a turbine needs to be between 2000 and 2500 h for an installation to be profitable.

Eighteen strategic wind plans have currently been approved, with 12 associated industrial projects. It is estimated that wind energy potential will reach 3135 MW of installed capacity from wind farms in 141 areas. The electric power generated corresponds to 700,000 toe with investment of over €3.5bn. Already over 2000 direct jobs have been created. These are distributed in factories manufacturing parts and auxiliaries (assemblies, towers, multipliers, blades and composites), which account for nearly half of the figure,

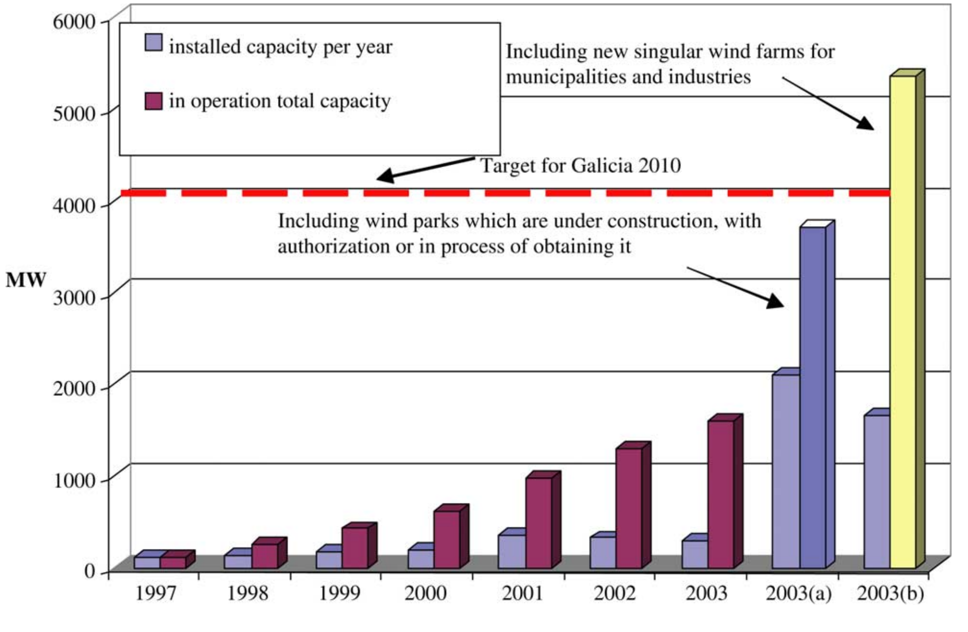


Fig. 5. Estimation for achievement of targets of the Galician wind plan.

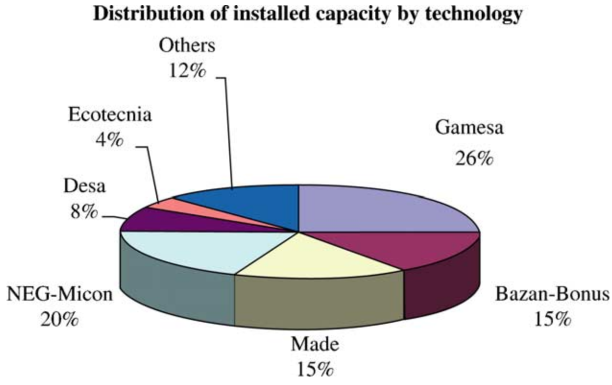


Fig. 6. Distribution of wind power by technology of wind turbines.

construction and engineering firms (35%) and farm maintenance (15%). In addition, 12 new companies from the industry have opened in the last 4 years, with a forecast of further installations.

Foremost of the relevant factors is windspeed, which depends on the elevation, exposure, roughness and steepness of the terrain concerned. Barriers to the use of wind energy lie in the limited location possibilities and in the transport capacity of the local electricity grid receiving the energy produced by the wind farm. This grid limitation will be a decisive factor when between 15 and 20% of total electricity consumption comes from wind power, which always depends on local conditions.

Galicia is currently the region of Spain with the largest installed capacity (25.5% of the national total in 2003) and also the region with the greatest potential for installation in the medium term future. It is important to note that the average capacity of the wind turbines installed in 2003 was 844 kW, with about 2750 turbines installed.

Fig. 5 shows trends in installed wind power capacity over recent years, with annual increases of 30%. It is worth noting that the capacity of the wind farms now under construction, those with authorisation from the authorities and those pending authorisation comes to about 2100 MW, giving a total figure of around 3700 MW. If we add the new special farms for municipalities and industries which have another 1653 MW of new capacity, we get a total of 5200 MW—ahead of the Wind Plan for 2010 in capacity and operating periods. Fig. 6 shows installed capacity based on the technology of the wind turbine manufacturers.

In order to demonstrate the importance of wind generation in Galicia, consider the coverage of a 31.35 MW wind farm with an estimated output of 43,750 kWh per year, which would be equivalent to consumption by around 15,000 inhabitants, with a production equivalent to that of a power station burning 65,000 t of brown lignite, 2650 h at full power.

2.1.4. Hydropower

2.1.4.1. Power stations with >10 MW capacity. Until the coming of cogeneration and other renewable sources, hydroelectric energy constituted the only renewable power

source in Galicia, and the only local resource of any scale that could contribute to meeting the region's energy needs. There are 34 hydro power stations of over 10 MW with a total capacity of 2759 MW, representing 17% of Spain's installed hydro capacity and between 38 and 50% of Galicia's—depending on rainfall—in any given year. Output in 2001 came to 767 ktoe. This is a mature technology in which no significant developments are expected, although efficiency might be increased at some stations by replacing equipment with more efficient units.

2.1.4.2. Small hydro (<10 MW). In 1998, Galicia had 57 small hydro stations, with a combined installed capacity of 115 MW. By 2002 the figure had grow to 81 stations with a total installed capacity of 169 MW. This represents 2% of installed capacity in Galicia and 7.5% of installed small hydro capacity in Spain. The contribution to the energy balance (as is the case with large hydro) depends on rainfall in the year under study [33].

Galicia has numerous sites with sufficient hydro potential to ensure the viability of small hydro stations. The potential is estimated at 200 MW, which could generate about 60 ktoe per year. However, for environmental reasons it is expected that no more than 100 MW will be installed. One priority is to minimize the ecological and environmental effects of energy projects. Growth is practically zero and if the situation remains unchanged, the targets set out in the White Paper [8] will not be achieved.

2.2. Green heat technologies

The term green heat is used to refer to technologies used to heat and/or cool spaces in both residential and commercial buildings as well as to heat drinking and service water. These technologies include: solar thermal water, geothermal and biomass systems.

Heat production in Spain [45] from renewable energy breaks down into the following technologies: in 2002, biomass came to 3414 ktoe, biogas 31 ktoe, biofuel 121 ktoe, solar thermal 40 ktoe and heat production: from geothermal energy came to 8 ktoe, giving a total of 3614 ktoe as compared to the 5125 ktoe forecast for 2010 in the Renewable Energy Promotion Plan.

2.2.1. Geothermal energy

The many thermal springs throughout Galicia are well known and have been used for therapeutic purposes since Roman times. However, it was not until 1979 that underground geothermal resources were researched and assessed. These studies have shown that the technically and economically exploitable geothermal resources are of low to medium enthalpy, with temperatures of between 50 and 140 °C, at depths of between 200 and 1500 m. Detailed analysis of the conditions of the reserves detected requires a differentiated treatment when it comes to considering their possible harnessing.

On the one hand, from the point of view of the underground hydrology, despite the high level of rainfall in the region, the lack of porosity in the rocks in the subsoil to a great extent prevents natural seepage of the water and its storage at the deeper layers. In practise, this means that there is a lack of important reserves, and it would therefore be necessary to apply what are known as 'dry hot rock' techniques, which would make the tapping of these geothermal resources difficult and expensive.

Attention needs also to be paid to the geothermal resources that outcrop at the surface in numerous parts of Galicia. The origin of these thermal springs, usually located in granite areas, probably lies in the seepage of cold water from a nearby river or stream, which penetrates the fractures in the terrain and is heated up as it reaches greater depths, and is then expelled to the surface again through the faults in the area.

Some previous explorations have been carried out but no possible geothermal resource exists that is being tapped for energy purposes. Direct utilization of geothermal energy has been considered in terms of heat pumps, aquifer thermal energy storage, energy of mine waters and hot spring resorts.

Ourense is the province which has the greatest potential for using geothermal energy. Indeed, the only project (apart from spas) of this type currently being undertaken in Galicia is in this province. The Burgas spring in the city of Ourense (with a temperature of 70 °C and a flow of 12 l/s) is used for two different applications. The first involves climate control of the swimming pools in the Municipal Pavilion in Los Remedios, through a 1200 m pipe with a flow of 5 l/s. The second application is for heating a block of 27 apartments, which are supplied from a collection point next to the main pillars of the building, with a plate exchanger and an accumulator with a capacity of 4000 l.

Of the water from mineral and thermal sources detected in Galicia, 42% is used for spas, 6% for bottling plants and 52% would be difficult to exploit. Thermal waters can be classified by temperature into athermal (0–20 °C), hypothermal (21–30 °C), mesothermal (31–40 °C) and hyperthermal (>41 °C).

Although the possibility of 329 spas has been mooted in Spain, only 128 are actually running, and Galicia, with 18, is the autonomous community with most in operation.

There are 38 geothermal sources in Galicia with a surge temperature of over 20 °C, although practically all are used in spas and thermal facilities. The potential of geothermal energy in Galicia lies between 120 and 130 ktoe per year. Nonetheless given its low temperature, it is rarely used to generate electricity.

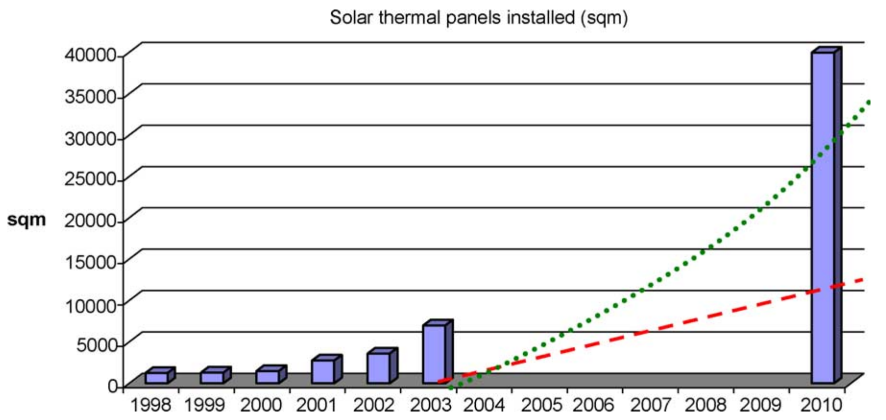


Fig. 7. Estimation for achievement of targets of the Galician solar thermal plan.

2.2.2. Solar thermal

Solar energy has traditionally been used in agriculture, in greenhouses, for sun drying crops, etc. However, the trend in recent years has been to use artificial drying systems, with high energy consumption. Of the total energy consumed in the primary sector, around 15% is used as low-temperature heat energy. Nevertheless, agricultural production is very seasonal, thus decreasing the number of days when the solar system is in operation.

The Instituto Energético de Galicia has started up a programme to promote the development of solar power in Galicia. Its main targets are: [39]

To multiply the installed surface area of solar heat panels by 15–40,000 m^2. To achieve an annual saving in primary energy of 3.1 ktoe through solar heat energy. To reduce atmospheric pollution from generation by over 32,000 t of CO_2, 37.4–39.2 t of SO_2 and around 50 t of NO_x per year.

In 1998, the total surface area of the solar heat panels installed in Galicia: was 1250 m^2, compared to 300,000 m^2 in Spain as a whole. In 2003, the area of installed panels increased to 7000 m^2 thanks to the ‘Programme for Promoting Solar Power in Galicia’, but this is still a long way from the forecast 40,000 m^2 which has been set as the target for 2010, as we can see in Fig. 7, which shows two possible growth hypotheses, one linear and the other exponential. In order to achieve this target, about 5000 m^2 will have to be installed per year.

As for the passive use of solar energy, i.e. so-called bio-climatic architecture, almost nothing has been done in this area. The incorporation of bio-climatic architectural elements (trombe walls, systems of direct gain, etc.) could also be considered.

2.2.3. Biomass

In Galicia, gorse has traditionally been used (*Ulex* spp.) as bedding for livestock, although it is beginning to be used for harnessing energy, at both residential level and in ceramics, glass, foodstuffs and thermal power stations. The use of firewood for homes in rural Galicia has had an important impact on the family economy, although this is not reflected in official statistics. The location and conditions of the biomass have a deciding effect on its price.

Because suitable forestry techniques are not applied to obtain quality saw wood, useful harnessing of wood comes to only 40%, with 50% in by-products, such as sides and sawdust, and 10% of waste, mainly bark. Of the waste generated in cutting the different types of wood on the mountainside, half comes from eucalyptus (*Eucalyptus globulus*) plantations.

Heat production (96.6%) comes from biomass. At present forestry biomass is primarily used through direct combustion for generating heat for domestic uses and industrial processes.

In heat applications in the industrial sector, the proposed target for 2010 is for use of 850 ktoe, with investment by 2006 of €241m; in the domestic sector the target is 50 ktoe, with investment of €110m. Summing up, the area of biomass is the most substantial feature of the plan contributing 63% to the energy targets).

2.3. Green fuel technologies (energy crops and biofuels)

These crops are harvested exclusively for obtaining products purely for energy use. They should focus on large production per unit of surface area over short periods of time, in order to compensate for the drop in added value from energy uses as compared to food crops. Although it may seem contradictory to use agricultural crops for energy needs, without first exploiting waste biomass, the fact is that such crops can be a viable alternative, as it is possible to obtain the biomass in a concentrated form and with the possibility of easy access to the material, instead of coping with the difficulties posed by waste biomass which may be widely dispersed.

Despite the broad potential for biomass in Spain the resources are underused. Energy crops account for 56% of the target for increasing biomass consumption, whereas there are practically no power stations for harnessing the resource.

With regard to biofuel [46], there are currently several research projects, among which one of the most important involves obtaining biofuel from gorse. A bioethanol plant has also been set up in the town of Curtis, which produces bioethanol from cereals, with a production capacity of 100,000 t per year (approximately 65 ktoe per year). Galicia plans to reach a figure of 100 ktoe in biofuel by 2010 when it will have the largest biofuel facility in Europe. The Spanish RE Promotion Plan establishes a target of 400 ktoe, with the Curtis plant accounting for 25% of the entire plan. It is also important to note the approval of Act 53/2002 governing Tax Measures [47] which modifies the legislative framework applying to biofuel, establishing a zero tax rate on hydrocarbons until 2010. Directive 2003/30/EC [48], on the promotion of the use of biofuels for transport, which sets a minimum sale limit of 2% in 2005 and 5.75% in 2010, with a minimum percentage in the form of mixture of 1.75%. Biofuels can be supplied pure, mixed with petroleum derivatives or as liquids derived from biofuels (ETBE). Given this situation, the figure in the Promotion Plan is likely to be changed to 2000 ktoe, in view of the forecast increase in consumption of petrol and diesel fuels.

The barriers to use that we may encounter lie mainly in the necessary tax exemption, separating production of raw material which must be withdrawn under the PAC, adapting the general distribution network for biofuels and getting guarantees from vehicle manufacturers. Specific barriers to bioethanol lie in the availability of isobutylenes to produce ETBE, while for biodiesel, the high market price of oils for food uses may be a barrier.

Finally, Council Directive 2003/96 (framework for the taxation of energy products) sets the objective of allowing member states to apply a reduction in special taxes (excise duty) to biofuels, under certain requirements. The main products eligible for application of the tax reduction between 1/1/2002 and 31/12/2010 are vegetable oils and animal fats, synthetic methyl and ethyl alcohols, energy products of biomass and water.

3. Achievement of EU targets-2010

In 2001, the European Commission issued a Directive on electricity production from renewable energy sources [42], where the community targets for the European Union,

in consonance with national targets, were as follows: to double the share of renewable energy sources in final gross energy consumption in Europe from 6 to 12% by 2010. To introduce the necessary measures to increase the share of green electricity in gross electricity consumption from 14 to 22% in 2010. To achieve a saving potential of 22% in the energy consumed in buildings (lighting, heating, air-conditioning, hot water) by 2010. To increase the share of biofuels in the total volume of fuel to 5.75% in 2010. Using reports prepared by the member states, the Commission will present a summary report on application of the directive to the European Parliament and the Council before 31 December 2005.

The leading recommendation agreed by the European Conference on Renewable Energy was that the European Union should set a new medium-term target: renewable sources should satisfy at least 20% of energy consumption by 2020. Achieving these targets would require investment of around €400bn to 2020. These costs, however, are more than offset by the forecast benefits: creation of 2 million new jobs in the EU; 17% reduction in emissions of greenhouse gases compared to 1990 and a saving in fuels and external costs avoided of between €240bn and €440bn.

According to the estimates of the Spanish Plan for the Promotion of Renewable Energy primary energy consumption in a saving scenario would stand at 135,000 ktoe in 2010. Nonetheless, latest forecasts from the Secretary of State for Energy indicate that primary energy demand would stand at around 169,593 ktoe due to the current growth in the Spanish economy. As a result, the targets established in the Plan for Promotion of Renewable Energy (16,639 ktoe) would represent 9.8% of demand in 2010—very much below the hoped-for figure of 12%. Given that this increase needs to be covered by renewable energy, about 3712 ktoe would have to be added to reach the figure of 12%,

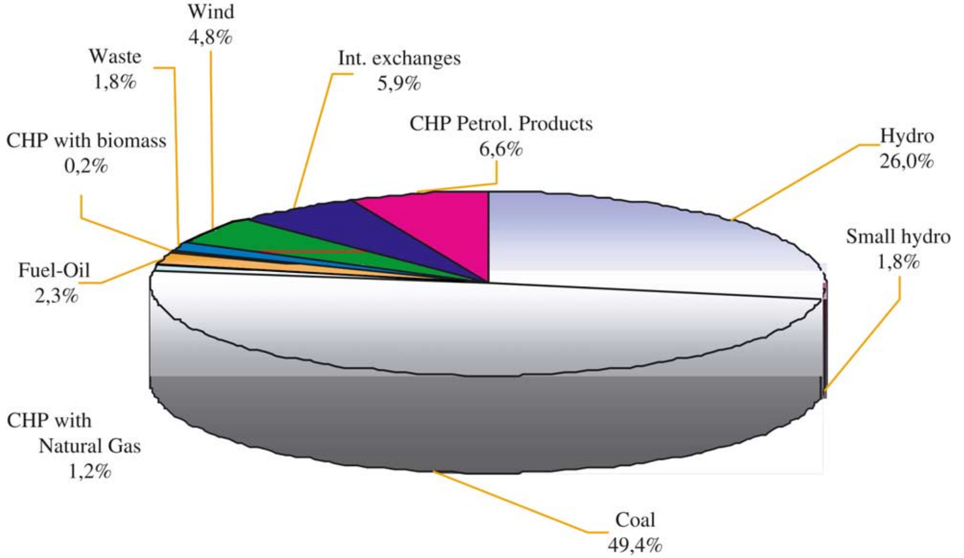


Fig. 8. Galician electricity mix (ktoe).

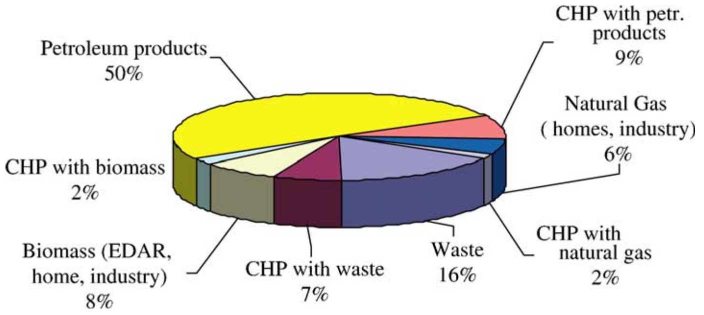


Fig. 9. Heat available for Galician consumption (ktoe).

which represents 22% more than the initial contribution forecast in the promotion plan. Most of this increase would have to come from wind power (new target 13 GW) and biomass (new target 3090 MW). At the same time, according to the latest forecasts on industrial development and development in small and medium-sized enterprises from the secretary of state for energy, electricity demand in 2010 would be about 276,000 GWh. In order to reach the national target (29.4%) of Directive 2001/77/EC [42] it would be

Table 3
Average equivalent hours for electricity generation, and conversion of electric MWh to toe in terms of primary energy

Source	Hours per year	toe/MWh
Hydro stations <10 MW	3100	0.086
Hydro stations between 10 and 50 MW	2000	0.086
Hydro stations >50 MW	1850	0.086
Photovoltaic	1700	0.086
Biomass and MSW	7500	0.378
MSW	7500	0.346
Biogas	7000	0.275
Solar photovoltaic	1700	0.393
Wind	2400	0.086

Table 4
Emission factors of CO_2

Source	$ktCO_2$/ktoe
Coal	4.032
LPG	2.614
Petrol	2.872
Diesel	3.070
Fuel-oil	3.207
Natural gas	2.337
Generation of electricity with coal, efficiency of power station 35.5%	tCO_2/GWh: 977
Generation of electricity with NG combined-cycle, efficiency 51%	tCO_2 /GWh: 394

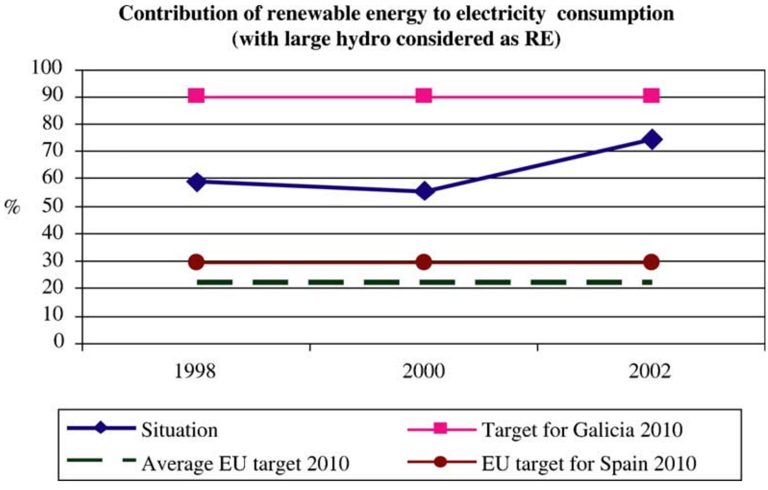


Fig. 10. Contribution of RES to power consumption (with large hydro).

necessary to generate 81,144 GWh with renewable sources, 6% more than the figure envisaged in the Promotion Plan (76,597 GWh).

Galicia is one of the autonomous communities which can help to achieve these new targets, given that it has very diversified power generation facilities, and this favours the reduction in potential risks from occasional shortfalls in supply (Figs. 8 and 9). Of the generating facilities with a total installed capacity of 7296 MW, 58% corresponds to power stations powered by renewable energy sources. The potential for use of renewable

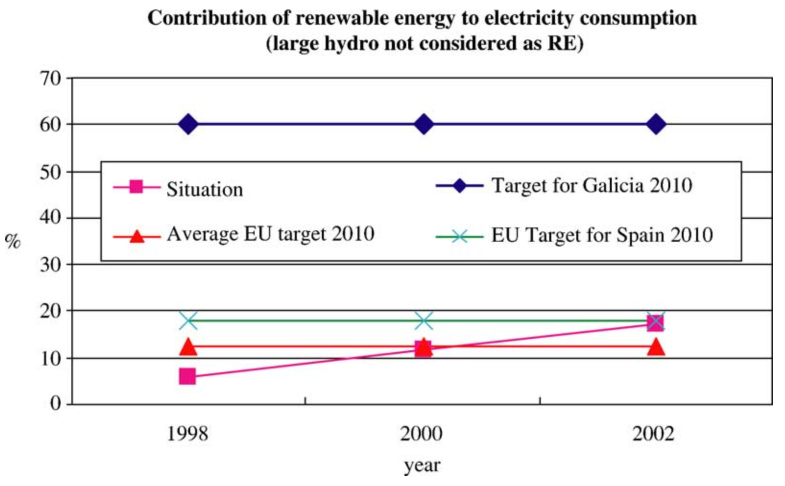


Fig. 11. Contribution of RES to power consumption of (without large hydro).

energy is very high and the subsequent socio-economic benefits that would be obtained by harnessing resources would be very significant.

There was an increase of 780 MW (11.9%) in total installed capacity in 2001 and 2002, of which 85% involved facilities powered by renewable sources and 15% CHP facilities.

The power envisaged in the wind plan for Galicia would provide: 51% of total electricity consumption in Galicia by 2010, generating an energy equivalent of 860,000 toe. It would mean a primary energy saving of 2,150,000 toe—i.e. the equivalent of 16 million barrels of oil with a saving of €440m per year. The main drawback is that it does not cover the power demanded by the system.

In view of the current situation and the forecasts for 2010 on each source of renewable energy, we may assume that Galicia will be able to cover its own electricity demand before 2010, thus clearly exceeding the targets set by the EU for Spain (19.5%). At the same time, it will be capable of increasing its power export capacity; the electricity exported could be of green power type (Figs. 10 and 11).

In order to achieve sustainable development, it is also necessary to take into account the emissions avoided. To make this calculation, the conversion factors shown in Tables 3 and 4 are used to comply with Kyoto Protocol targets. The Spanish commitment is for an increase during the period from 2008 to 2012 of $<15\%$ (compared to 1990), but the current situation at Spanish level is very different: there was an increase in CO_2 emissions in 2001 of 32% (compared to 1990), making this commitment difficult to achieve.

In 2002, renewable energy sources in Spain prevented emission of 14 million tonnes of CO_2 and the importation of 1.5 million tonnes of oil equivalent. In 2002, renewable energy sources accounted for annual investments of more €1.6bn and the maintenance of 25,000 direct jobs and 75,000 indirect ones [49].

The Autonomous Community of Galicia contributed to this reduction in emissions with an increase in renewable energy facilities representing approximate values for 2002 of a reduction of 5800×10^3 t of CO_2 per year, practically half coming from the use of wind power and the rest from large hydro, whereas the target established for 2010 for emissions is $12{,}600\times10^3$ t of CO_2 per year, meaning that half of the final target has now been reached.

4. Conclusions

To achieve the beneficial effects of harnessing renewables, a series of actions needs to be taken in Galicia. In general terms, these include: incentives for preparing a supply/demand market with a certain degree of stability; search for incentives and financial formulas that will propitiate investment in this field; development of the pilot projects, evaluating the savings achieved, the environmental impact, etc. and promoting awareness of the results.

In short, given the great potential for available energy resources, the future for renewable energies in Galicia looks good, since they can contribute significantly to regional development. It may therefore be concluded that in coming years Galicia will meet the European Union's targets. In addition, given the great potential of renewable resources, Galicia has set itself considerably more ambitious targets based on development of renewable energy such as small hydro, biomass or solar and primarily wind power.

Despite the broad potential for biomass in Spain the resources are underused and biomass energy therefore offers a magnificent development opportunity which should be encouraged in coming years. In this way it is hoped that electricity self-sufficiency can be achieved by 2010, 51% of which will come from wind power, with a saving of 4000 ktoe in primary energy, and avoiding emissions of about 12×10^6 t of CO_2 per year.

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